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A PRELIMINARY COMPARISON OF RANGE ESTIMATION USING BLACK-AND-WHITE TELEVISION AND THE UNAIDED EYE

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HUMAN ENGINEERING LABORATORIES

ABERDEEN PROVING GROUND,
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ABSTRACT

This investigation compared how accurately target ranges can be estimated from two modes of observation -- viewing a black-and-white television (TV) monitor, and viewing with the unaided eye. For each mode, the subjects made four estimates at each of five distances -- 100, 300, 600, 800, and 1000 yards.

Two conclusions were indicated: (1) subjects could estimate absolute distance when viewing the TV monitor; and (2) there were significant differences between the subjects' constant errors in the two modes.

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A PRELIMINARY COMPARISON OF RANGE ESTIMATION

USING BLACK-AND-WHITE TELEVISION AND THE UNAIDED EYE

INTRODUCTION

Accurate range estimation is an important element in many Army combat operations. Even with advances in instrumental control of ranging and aiming, the necessity of human judgments of distance in many military operations has not been eliminated. In the event that television is used as a visual aid for remote observation of combat operations, one must consider the observers' ability to estimate target distances from viewing a television (TV) monitor.

In examining the observers' ability to estimate target distances, one must consider the cues for distance perception. According to Gibson (4), when a target is located on the ground, the surface between the observer and the target will provide perspective and texture gradients corresponding to varying distances. When target size is known, the apparent size of the target is another cue for distance, independent of the perspective and texture gradients.

The predominant cues for distance perception -- apparent target size, linear perspective, and texture gradients -- are present when viewing a three-dimensional scene with the unaided eye. If these same cues for distance perception are present when viewing a two-dimensional scene (TV monitor), then there should be no significant differences in estimating distances between the two modes of observation (TV and unaided eye), except as color might affect them.

This investigation was conducted to determine whether subjects could estimate distances from a TV monitor, and to compare the accuracy of estimating target distances from viewing a TV monitor with the accuracy of estimating them with the unaided eye. It was hypothesized that (1) the human observer would be able to estimate range from the TV monitor, and (2) the accuracy of range estimates would not differ significantly as a function of the mode of observation (TV and unaided eye).

METHOD

Subjects

Twenty-five enlisted men stationed at Aberdeen Proving Ground, Md., served as subjects (Ss). The Ss' ages ranged from 18 to 29 years. The Ss' far vision ranged from 20/30 to 20/15, as determined by Ortho-Rater tests.

Apparatus

The equipment for the TV presentation consisted of a General Precision Laboratories P.D.-152 closed-circuit TV system. A 21-inch TV monitor was placed in the front of a semitrailer van (Fig. 1). The TV camera was placed at one end of a level 1200-yard road. A shutter was placed over the camera lens to conceal the target's movement while it was being positioned.

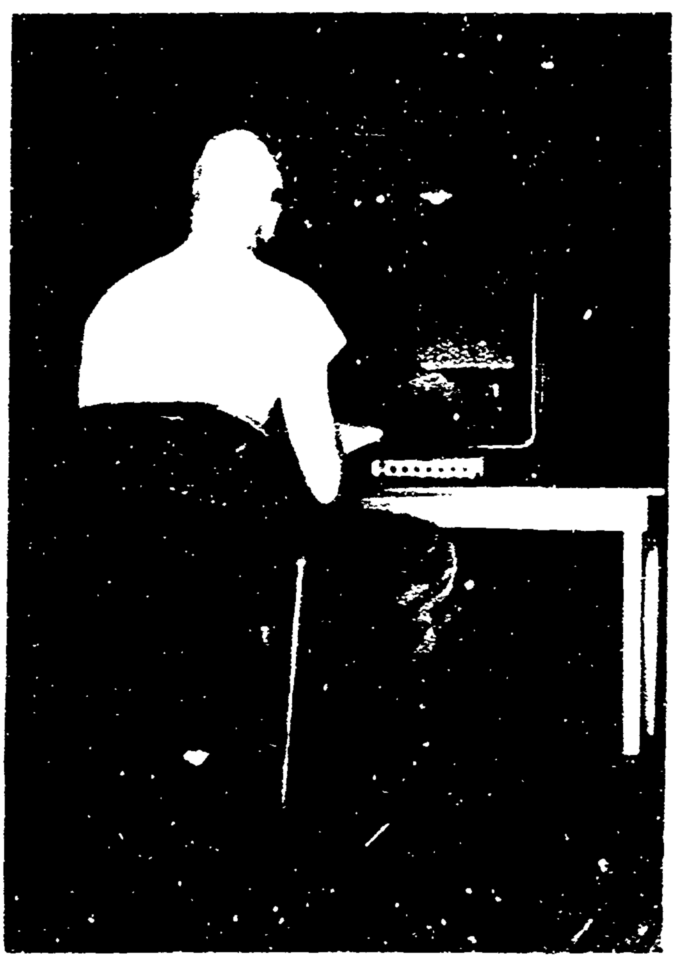

Fig. 1. SUBJECT VIEWING TV PRESENTATION OF THE TARGET

For the unaided-eye presentation, a 4' x 8' piece of plywood was placed beside the TV camera, between the observer and the target (Fig. 2). An appropriate rectangle, corresponding to the field of view of the TV camera (using a fixed S position) and at the same height as the TV monitor, was cut in the plywood. A shutter was placed over the opening in the plywood to conceal the target's movement while it was being positioned. Figure 3 shows the experimental arrangement.

A single target was mounted on the back of a jeep which could be moved to the various target loci. The 8' x 12' tombstone-type target was made of expanded aluminum (Fig. 2). The entire target was painted white.

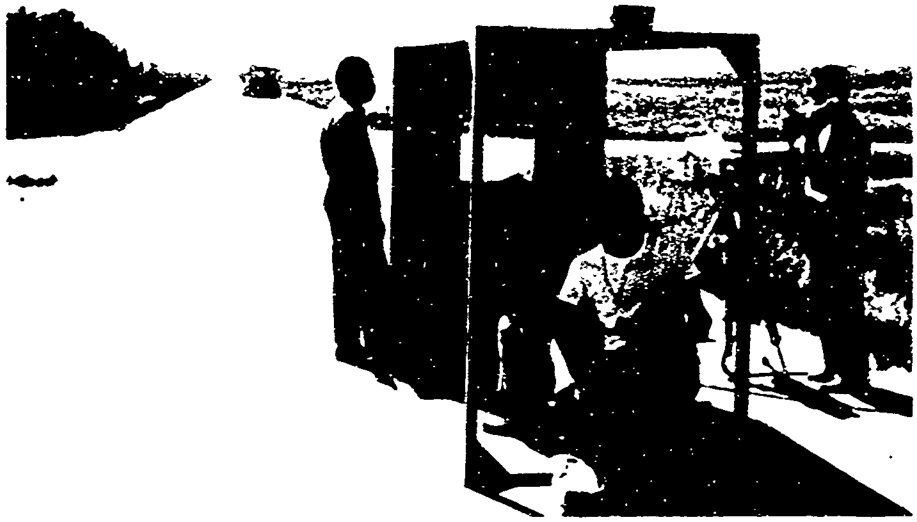

Fig. 2. SUBJECT VIEWING THE TARGET IN THE UNAIDED-EYE MODE

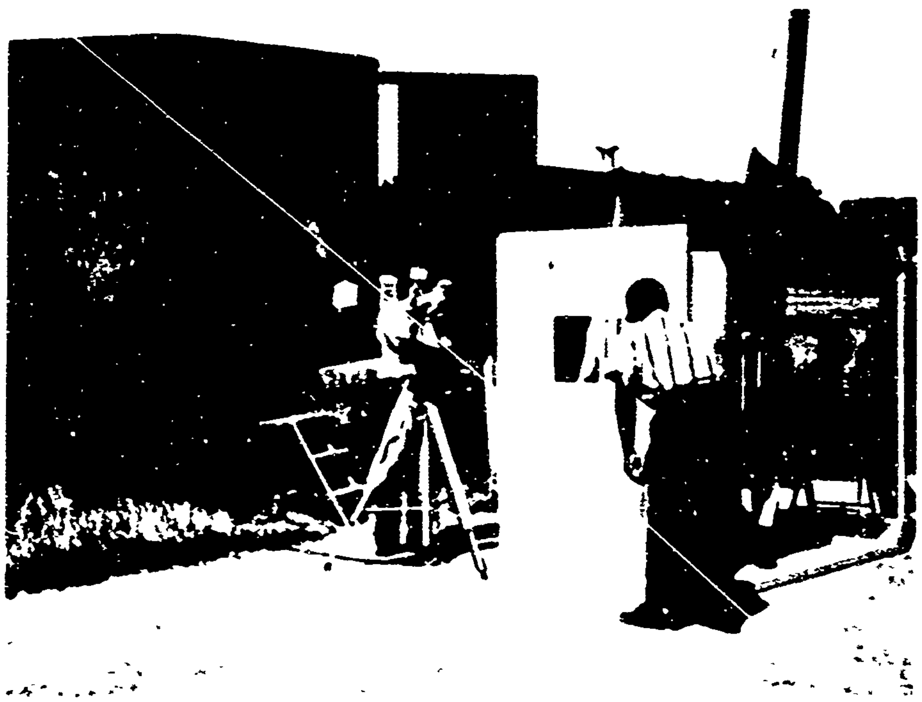

Fig. 3. EXPERIMENTAL ARRANGEMENT OF APPARATUS FOR THE TV AND THE UNAIDED-EYE PRESE TATIONS

PROCEDURE

The experiment was carried out on 1200 yards of hard-surface road in a level field. Trees and buildings were not visible at the sides but were visible near the end of the 1200 yards. However, the Ss had an uninterrupted view of the entire course. The Ss were seated six feet in front of the TV monitor or the plywood panel. A practice trial was given for both modes of observation before the test began. The practice trial consisted of presenting known target distances to the Ss. The target was positioned at each of the five distances (100, 300, 600, 800, and 1000 yards); and at each distance, the Ss were told the target range.

After the one practice trial, the experimenter closed the shutters on the TV camera and the plywood panel. The experimenter radioed the jeep driver to move to the first position. Then the experimenter opened the shutters, and the Ss made their range estimations. The shutters were closed again, and the jeep driver was told to move to the second position, etc. At the end of 20 trials, the Ss exchanged modes of observation. Another practice trial was given, indicating the correct target ranges, and the procedure continued as on the first 20 trials.

The Ss were asked to make absolute judgments, in yards*, of the distance from their position or the camera position to the target. Each S served as his own control and made four estimates at each of the five distances for each mode of observation. The five distances were randomized among the 20 trials, with the restriction that each range appeared four times for each mode of observation.

The Ss were given the following instructions:

"In this experiment you will be seated in front of a television monitor or a plywood panel. Your task is to estimate ground range in yards as accurately as you can from your position to the target. The target will be set at various ranges in a randomized manner. You should look at the monitor or through the plywood panel only when the experimenter gives the signal, then write on your answer sheet your estimation in yards of the distance from you to the target.

"You will be given a view of the target, which is 8' x 12', at various distances up to the maximum range to be estimated before the test begins. These positions may or may not be the actual test positions.

"If the TV fails at any time, notify the experimenter. Are there any questions?"

* Yards were used because the Ss were not sufficiently familiar with the metric scale.

RESULTS

The Ss' mean estimates of target distance for the five ranges and the two modes of observation (TV and unaided-eye) were transformed into five-place logarithms, since previous studies (1, 2) have shown the utility of such a conversion. The logarithmic transformation permitted the use of geometric means of the distance estimates.

Table 1 gives the geometric means of the distance estimates and the standard deviations (SD)* for each of the five target distances (in yards). The relationship between the true distance and the mean estimated distance was linear, as previous studies have found (1, 2); thus perceived distance increased as real distance was increased. The Ss tended to overestimate at four of the five ranges when estimating range from the TV monitor; but with the unaided eye, they overestimated at only two of the five ranges and underestimated at the other three. The means of the TV range estimates were larger than those of the unaided-eye range estimates for every range; however, the results of a Sign test (5), indicated there were no significant differences in the means of the distance estimates for the two modes of observation.

Although the means of the distance estimates did not differ significantly, the variability of the distance estimates was reflected by the SDs. The SDs (Table 1) of the TV range estimates were larger than those of the unaided-eye range estimates for every range except the 1000-yard range. The SDs did not appear to vary with distance in any consistent way, for either mode of observation, but there was some tendency for the SD to decrease as distance increased for both modes of observation. This tendency was also found by Gibson and Bergman (1, p. 477), who indicated it may be a "function of end-anchoring, i.e., the farthest point on the scale becomes a well-defined reference point and causes Ss' judgments near the end of the field to center closely around an estimate associated with the end of the distance scale."

Since the SDs indicated some variability between the two modes of observation, the individual error scores for the TV and the unaided-eye range estimations were compared by obtaining a constant error of estimation for each S on each mode of observation. The Ss' constant errors in estimating range with TV exceeded the Ss' constant errors in estimating range with the unaided eye in 17 of the 25 cases. In six cases the Ss' constant errors from the unaided-eye range estimates exceeded the Ss' constant errors from the TV range estimates, and in the remaining two cases, the Ss' constant errors were equal. The constant errors from the two modes

* As indicated in a previous study (1, p. 477), "The SD, in logarithms, is converted into a ratio by finding the antilogarithm; this, times the geometric mean, gives a score one SD above the mean; and divided into it, one SD below."

of observation were then ranked, regardless of sign, and compared using Wilcoxon's nonparametric test for paired replicates (5). The Ss' constant errors in estimating range with TV exceeded the Ss' constant errors in estimating range with the unaided eye, at the .05 level of confidence. In other words, the Ss had a significantly larger constant error in estimating range with TV than in estimating range with the unaided eye.

The effects of the order of presentation were examined by comparing (1) TV estimates before and after unaided-eye trials, and (2) unaided-eye estimates before and after TV trials. The results of a Mann-Whitney U test indicated there were no significant differences. Thus the effect of order of presentation was not a significant variable in this investigation.

TABLE 1

Geometric Mean Estimates in Yards
and Standard Deviations
for Targets at Varying Distances

	Unaided Eye		Television	
True Distance	Mean Estimates (yards)	SD (yards)	Mean Estimates (yards)	SD (yards)
100	99.76	2.68	100.50	49.09
300	308.96	52.24	343.10	115.95
600	600.86	81.65	617.80	112.95
800	786.76	75.91	796.10	78.61
1000	970.70	71.41	1012.70	56.27

DISCUSSION

The results indicated that the Ss were able to make distance estimations from a TV monitor. In the unaided-eye mode, the means of the distance estimates were very close to the true distance, and the SDs were fairly consistent, except for the 100-yard range (Table 1). In the TV mode, the means of the distance estimates were also close to the true distance; however, the SDs were larger at the shorter ranges than those for the unaided-eye presentation. Gibson and Smith (3) suggested, in an experiment using photographs, that Ss are likely to learn rather specific cues in a photograph during practice, and to improve their distance estimates by associating these cues with the responses that are reinforced. The comparatively accurate estimates given in both modes might arise from learning specific cues in the preliminary trials. With the procedures used in this study, these cues were probably associated with the correct responses in the practice trials. The resulting learned associations between these cues and the correct responses could account for the accuracy of the distance estimates within each mode of observation.

Although the means of the distance estimates were not significantly different, the Ss' constant errors in estimating distance with TV were significantly larger than the Ss' constant errors in estimating distance with the unaided eye. While the predominant cues of distance perception -- such as apparent target size, linear perspective, and texture gradients -- were present in both modes of observation, several other factors could have accounted for the observed differences between the Ss' constant errors. The two-dimensional stimuli from the TV picture plane may have had some effect on the Ss' constant errors. Gibson and Smith (3, p. 4), in their photograph experiment, said:

> "One difficulty with the use of a photographic test of distance perception, rather than an actual three-dimensional test, is that there are two-dimensional stimuli from the picture plane itself which may complicate or interfere with the perception of a three-dimensional scene."

There was an apparent difference in the target sizes in the TV and unaided-eye presentations. On the TV screen, the target appeared smaller than it did in the unaided-eye presentation. In general the TV estimates at each distance were larger (i.e., greater ranges) than the unaided-eye estimates. It could be hypothesized that the difference in apparent target size in the two presentations accounted for the difference in the Ss' constant errors in estimating distance. However, such things as presence or absence of color, differences in resolution and other inherent TV characteristics, and differences in motion parallax could also account for the observed differences in the Ss' constant errors.

SUMMARY

In a preliminary investigation, 25 Ss estimated absolute distance under two modes of observation (television and the unaided-eye). Every S made four estimates at each of five distances -- 100, 300, 600, 800, and 1000 yards -- with both modes.

The results suggested the following conclusions:

a. The Ss were able to estimate absolute distances from a television monitor.

b. Although there were no significant differences between the means of the distance estimates with TV and the unaided eye, there were significant differences ($p < .05$) between the constant errors of the Ss' TV distance estimates and those of their unaided-eye distance estimates.

c. It was suggested that the Ss made larger constant errors on the TV mode of presentation because the apparent target size was smaller on the television monitor.

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